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## (54) IMPROVEMENTS IN THE MANUFACTURE OF STEEL CONTAINERS

(71) We, AMERICAN CAN COMPANY, a corporation organised and existing under the laws of the State of New Jersey, United States of America, residing at American Lane, Greenwich, Connecticut 06830, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to improvements in manufacture of steel containers such as cans.

Metal containers may be formed by any of various techniques including drawing and ironing, drawing or multiple draw techniques.

Drawn containers are manufactured by forcing a metal blank into a die while the blank is prevented from wrinkling by pressure exerted on a clamp plate. The clearance between the punch and die is such that the metal is not pinched or thinned, i.e. the drawing operation changes a flat blank into a hollow vessel with little change in its thickness. Drawn cups can be redrawn when taller cups are desired. A typical operation would involve the steps of blanking from sheet metal, drawing a blank into a shallow cup, thereafter feeding the cup into another die of smaller diameter to make it taller; subsequent drawing is repeated as desired in progressively smaller dies until a cup of required dimensions is obtained. Through all of such steps although the metal has changed shape several times, the sidewall and bottom of the shells are essentially the same thickness as that of the original blank with a substantial reduction in the inside diameter of the cup.

As used herein, the term "drawing" is used relative to the can-making industry and is defined as the forming of recessed parts by forming metals in dies, and refers to the operations wherein a peripheral margin of flat stock is turned inwardly and simultaneously smoothed by means of a punch and drawing die to form a cup having a wrinkle-free sidewall the thickness of which is neither substantially less nor substantially greater than the thickness of the original blank.

In contrast to drawing techniques, including deep draw or multiple draw procedures, manufacture of containers by a drawing and ironing procedure involves forming a cup from a relatively thick sheet of metal and then reducing the thickness of the sidewall of the cup by pushing it on a cylindrical punch or mandrel through a series of ring-like ironing dies. Each of these ironing dies has a slightly smaller inside diameter than the preceding one in the series. The metal is squeezed or ironed between the punch and the ironing rings and is forced up the punch to form a tall cylindrical shell with walls thinned or reduced substantially from the original thickness of the metal stock.

As used herein, "ironing" will designate the forming of a thin walled wrinkle-free cylindrical structure with sidewalls thinned from the original thickness without substantially reducing the inside diameter of the cup.

Such drawing and ironing procedures, hereafter referred to as D & I, are accompanied by several problems of manufacture usually associated with the high radial surface pressure exerted on the dies. Because of this pressure, it is necessary to use materials of very high strength and having a high modulus of elasticity for the production of the dies and tooling. The high radial surface pressure also results in a considerable frictional force between the body of the container and the ironing dies, necessitating that provision be made for a lowered coefficient of friction. This has generally been accomplished by providing a polished die surface with intensive lubrication using oily, greasy

lubricants together with intensive cooling of the dies and/or punch. Chemical roughening and mechanical roughening have also been proposed as methods to deform the workpiece surfaces so that lubricant can be retained to aid in lubrication.

The workpiece itself may be such metallic materials as steel and tinplate, and the manufacturing process may involve either blank-fed or cup-fed ironing depending on the metal. With tinplate, for example, it is possible to form a D & I container shell directly from a flat blank of metal from a single stroke of a punch. In this procedure, circular blanks are cut from lubricated coil or sheet and are fed directly into an ironing press. The first die in the press forms a cup around the punch and irons the cup wall slightly. The punch then continues down through a series of dies which thin the sidewall to its final thickness. Such a procedure is possible with tinplate because of the great strength and drawability of steel. However, the high tensile and yield strength of steel, variations in sheet thickness and its low ductility have given rise to many problems associated with the extreme mechanical deformation encountered during D & I procedures.

Particularly extensive galling and die wear due to metal-to-metal contact occur unless tin is present on the surface of the steel to be formed.

A cup-fed procedure involves a separate cupping press for forming a cup. The cup-fed ironer has a die stack similar to that employed for the blank-fed process except that it is preferably turned 90 degrees so that the punch moves in a horizontal plane and gravity can be used to assist cup-feeding. Cups are generally relubricated after forming and prior to ironing.

Aside from the different feed mechanisms dictated by the particular metal, there are problems met in providing D & I containers which, although common in many respects, have been different in specific ways that relate to the specific metal. It is customary to change the ironing dies, coatings, decorating, bake temperatures, etc. to suit the properties of the metals to be shaped. With any metal, however, reduction of frictional forces during the operation has been a major problem. Oily, greasy lubricants, though effective, have been less than ideal since they must be removed and they add to the expense of the operation. Because of low viscosity, lubricating films break down at localized, highly stressed points resulting in a chain reaction of galling of both tools and product.

Various organic coatings have been used in drawing, multiple draw or deep draw operations wherein blanks are precoated with various substances and then formed. Our U.S. Patent No. 3,206,848 proposed deep drawn containers produced from a metal stock precoated with organic coatings by a method of baking the coating, drawing the metal, rebaking the coating, redrawing the metal, etc. Attempts to utilize similar and other prior procedures utilizing precoated steel or tinplate stock in a D & I operation have not been successful particularly because of the extreme stresses imposed on the coating during the ironing operation, the buildup of heat in the apparatus which often leads to the thermal breakdown of the coating, and the frictional forces experienced which tend to exfoliate the coating.

In U.S. Patent No. 3,577,753, it has been proposed that dry film lubricants precoated on metal stock could be utilized in a D & I procedure if the apparatus employed were modified to provide an internally fluid-cooled punch while circulating cool air over the dies and metal blanks. In such an apparatus, the surface temperature of the blank, punch and dies is maintained at 50°F or below to avoid decomposition of the lubricant. Such a method and apparatus is obviously not the solution to the major and diverse problems encountered in the drawing and ironing of precoated metal stock, particularly since it introduces the need to circulate cold fluid with attendant means for circulating and cooling the fluid, adding to the expense of the procedure. Additionally, it introduces the need for constant monitoring to assure that the temperature of either the punch, die or workpiece does not exceed 50°F to prevent decomposition of the film lubricant.

A method of forming D & I containers from precoated metal stock, suitable for application to steel or tinplate and employable in either a sheet or cup-fed process, would be a highly desired and much needed tool in the can-making industry. It is to this need that this invention is directed.

The present invention provides a method for drawing and ironing a seamless container from sheet steel or tinplate stock having an organic resin applied thereto prior to drawing and ironing. In the method to be described in detail hereinafter, an organic resin is applied to ferrous metal sheet and is retained on the metal both during and after the metal is subjected to drawing and ironing. Preferred resin films having suitable viscoelastic properties to permit plastic flow of the resin at the stress levels necessary to cause plastic flow in the metal include epoxy-phenolic, epoxy-urea formaldehyde, vinyl organosols and solution vinyl resins, either singly or mixed with one or more of the others. The above

resins could also be used as the active ingredient in other coating resins. Exfoliation or decomposition of the resin film during drawing and ironing is substantially absent when the preferred resins are employed. The invention can also simplify the manufacture of a drawn and ironed container from ferrous metal since it is possible to eliminate or substantially reduce subsequent manufacturing steps. The preferred resins can serve as a passivating coating on the inside container surface to guard against dissolution of the metal and consequent contamination of the contents of the container. Also, these resins can provide a satisfactory base coat for subsequently-applied printing inks or decorative film labels.

The invention also comprehends drawn and ironed steel or tinplate container bodies provided with coatings of the preferred resins, and finished containers comprising such container bodies fitted with top end closures.

The invention will now be described in more detail by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a schematic sectional view of a D & I die stack, showing a cup fed ferrous metal workpiece in the various stages of progression through the dies.

Figure 2 is a schematic sectional view of a D & I die stack showing a blank-fed ferrous workpiece, in the various stages of progression through the dies.

Figure 3 is a sectioned view of a ferrous container body formed in accordance with the invention with bottom profiling, after necking-in and flanging, the container having an organic resin applied thereto.

Figure 4 is a graph showing the relationship between cure temperature and ironing forces exerted as determined by a screening procedure when forming metal stock carrying an organic resin according to the invention as determined by the screening procedure.

The method of forming D & I containers according to the invention broadly comprises the steps of:

a) applying an organic resin to one or both of the opposite surfaces of flat metal sheet;

b) subjecting the sheet carrying the resin to an elevated temperature for a period of time sufficient to effect adhesion to the metal and a partial curing of the resin;

c) forming a workpiece from the organic resin-carrying metal sheet;

d) forcing the workpiece through drawing and ironing dies on a punch, to form an elongated cylindrical article the sidewalls of which are substantially reduced in thickness compared to the thickness of the metal sheet initially, and

e) removing the article from the punch;

the resin being cured in step b) to the extent that it is retained on the metal sheet, is capable of effecting a lowered coefficient of friction, and exhibits plastic flow (i.e. with respect to the metal and tooling) at high stress levels during the drawing, ironing and removing steps.

More specifically, an organic resin is applied to a ferrous metal sheet blank which can include blackplate, tinplate or other chemically treated steel. The resin-carrying metal sheet is then subjected to an elevated temperature, for example by baking in an oven, for a time sufficient to effect curing of the resin to such an extent that it is capable of functioning as a film lubricant, the aim thereof being to effect a lowered coefficient of friction between the workpiece and the ironing dies under loading up to a temperature of about 500°F. Because of the viscoelastic properties of the resin it prevents metal-to-metal contact at surface asperities while the workpiece is forced through a series of drawing and ironing dies. Preferably, the resin is cured to such an extent that it is capable of exhibiting the following characteristics during the drawing and ironing steps:

1) that it will require exertion of an ironing force of less than about 10,000 pounds and a stripping force of less than about 1200 pounds as determined by a screening technique set forth hereinafter;

2) that it will exhibit good elongation, compression and plastic flow under loading at temperatures up to about 500°F;

3) that it exhibits malleability with good adhesion to the metal sheet without adhesion to tooling:

4) that it will be abrasion resistant;

5) that it will be capable of reflow at temperatures up to about 500°F;

6) that it will be capable of maintaining adhesion to the underlying metal sheet during drawing and ironing without severe exfoliation;

7) that it will be capable of being cleaned, top-coated and rebaked without decomposition or loss of adhesion;

8) that it will prevent rust or corrosion of formed containers during storage prior to subsequent operations such as decoration or top-coat spraying;

9) that it will not affect the flavour or odour of products packed in the container and will act as a barrier to metal ion dissolution of the container metal into the product; and

10) that it will be capable of withstanding subsequent metal forming operations such as bottom doming and top necking-in and flanging.

The stripping and ironing forces recited

herein are those obtained on a cup-fed Stolle bodymaker, Model No. HX50-20, Serial No. 561190-2, (Stolle Corp., Sidney, Ohio) for a 211 diameter can with a five die stack. Strain gauges on the ironing ram were employed to determine peak ironing force by measuring the compressive loading of the ram during ironing and the negative compressive forces, i.e. tensile forces, as the ram withdraws and the formed shell is stripped therefrom. While the forces recited have been found to be reasonably consistent when employing various types of bodymakers, to the extent that it is possible that these values may vary, utilizing different apparatus, tooling, etc., they are viewed as a screening technique for evaluating cure conditions and the ability of specific resins to function in the D & I process and are given for purposes of illustration only. Curing of the coating to the extent that it is capable of exhibiting plastic flow with respect to the metal and tooling at high stress levels, of lowering the coefficient of friction during the forming operation and of being retained on the workpiece surfaces is the essential criterion for reasons discussed further hereinbelow.

The resins utilized herein may be any thermoplastic or thermosetting resin capable of exhibiting the characteristics above defined. A varied and diverse selection of resins is possible including resins selected from the classes of epoxy-phenolic, epoxy-urea formaldehyde, vinyl organosol, and solution vinyls.

The applicability of these resins in a D & I procedure is surprising and unexpected due to their diversity in type and particularly since attempts to utilize other types of resins have resulted in exfoliation and/or total removal of the resin, or in the resin becoming liquid and exhibiting "run-off" with little or no effect, resulting in galling, die wear, tensile failure and "earing" of the workpiece during forming. While the exact physical and/or chemical phenomena that are responsible for the results obtained are not known, one very important function of the bonded resin is believed to be in its behavior as a film lubricant, i.e., as a "plastic solid" material interposed between the workpiece metal and the tooling which serves to lower the coefficient of friction permitting a lower punch force and lower stress levels in the container wall. However, many failures in the drawing and ironing process are triggered by "stress risers", i.e., highly localized points of weakness caused by metal flaws or metal-to-metal contact between the workpiece and tooling which are not necessarily eliminated by placement of a lubricant to lower the coefficient of friction between the workpiece and tooling. For example, the metal exhibits plastic flow in the dies at a stress level beyond the yield point defining the onset of plastic flow in the metal. At that stress level, a localized breakdown of the film or films separating surface asperities on the workpiece and tooling could lead to a stress riser for any of the following reasons: metal-to-metal contact causing a "stick-slip" disruption of plastic flow; metal-to-metal contact causing spalling of surface asperities generating particulate abrasive material to damage films, workpiece walls and tooling; welding of foreign particles to previously smooth tooling surfaces; and/or localized heat generation sufficient to change the properties of the films or metals involved.

It is believed that the resin films employed herein, apart from lowering the coefficient of friction between the workpiece and the D & I tooling, also tend to distribute localized high stresses due to surface irregularities over a wider area through the plastic flow of the film which is controlled by the stress state present as the container passes through the different operations of the D & I process. In contrast to Newtonian fluids such as water, oils, etc., which show a direct proportionability between stress and shearing velocity whereby internal slippage will occur in the film at any stress level, the plastic films employed herein appear to resist flow until a certain yield shearing stress is imposed. This yield stress is construed as the stress that must be exceeded before the cured, bonded film begins to flow. The distinction is believed to be a significant one, since the resin film at a high stress level will be capable of functioning as a high viscosity "filler" thereby minimizing the effect of surface irregularities and resisting breakdown, yet below that stress level, will resist flow and serve as a film lubricant, characteristics that Newtonian fluids cannot exhibit. Moreover, since in the D & I process, radial compressive stresses imposed by the tooling are transmitted to the metal through whatever resin or lubricant films are present, it is essential, if the effect of the film is to be maintained throughout the process, that the plastic flow characteristics of the resin be compatible with the flow characteristics of the metal and that the film permit the development of higher stress levels without film failure. The D & I process involves at least four distinctly different operations, namely: blanking or cupping, drawing or redrawing, ironing and stripping. The film requirements are different for each operation because of variations in stresses inherent to each. The process increases the surface area of the metal so that elongation characteristics of the film are important if a

major portion is to remain bonded to the metal surface. Additionally, localized compression of the film, which may affect film adhesion even more seriously than elongation, is necessarily present in the cupping and redrawing operations with the effect being most pronounced at the open end of the shell where the metal has moved through the greatest radial displacement from the cut edge of the flat blank. It has been found that the shearing stress history of the film varies with location depending upon which of the four operations and which portion of the counter wall is under consideration. The requirements therefore for a film applied on flat metal which will be functional in all the operations are much more stringent than those for any one of the operations alone.

The resin films employed herein are believed satisfactorily to combine the necessary viscoelastic properties including suitable contraction and elongation; the ability to reduce the coefficient of friction between workpiece and tooling as well as the ability to resist plastic flow until a yield stress is imposed after which the resin flows distributing and minimizing the stresses during the process.

Measurement of the punch force required to move the workpiece through the die stack is used to show apparent changes in the coefficient of friction due to the presence of the resin film on the metal surfaces by the screening technique discussed hereinafter and provides significant information from a few samples for evaluating resins.

The successful operation of the resin types above enumerated and the characteristics exhibited are believed to be a function of the degree of curing to which the resin is subjected prior to forming. It has been found that there is a direct relationship between the extent of cure in terms of temperature and time and the characteristics exhibited by the resin as well as the forces that are exerted during the forming steps. It has been found, for example with the epoxy-phenolics, that short high bakes, for example at 400—425°F for 5 seconds are equal to a bake of six minutes at 300°F in terms of the ironing and stripping forces exerted during the operation. High bakes for longer times, e.g. at 400—425°F for six minutes, result in considerably higher forces that lead to detrimental results in the procedure. It has been found, maintaining the time, apparatus, i.e. punch and dies, metal, resin weight and resin as constants, that:

1) as the bake temperature increases, the ironing forces generated during forming increases. During ironing, the resin film is subjected to high radial stresses inside the die stack. Plastic flow of the resin during this stage is believed to be beneficial and a function of the high stress level.

2) as the bake temperature increases, the stripping force decreases. The stripping action takes place outside the die stack and in this state, the stress level is a function of the strength of the can wall. Here, springback and resistance to plastic flow are beneficial in resisting drag caused by surface asperities on the punch; and

3) as the bake temperature increases, the integrity of the film on the formed container becomes less than optimum.

The different curing temperatures appear to influence the film properties necessary for successful functioning herein. A high baking temperature for a period of time sufficient fully to cure the resin leads to a harder, more brittle film having flow properties that are other than characterized above and such a hard or brittle film may lead to a scraping action in the tooling which removes portions of the film from the metal surface and requires a higher punch force to move the workpiece; moreover galling and exfoliation of the film often result.

Graphical representation of these relationships may be seen in Figures 4 and 5 which were taken employing CMQ steel precoated with an epoxy-phenolic resin and baked for six minutes at the temperatures illustrated.

The optimum conditions herein are thus those wherein the resin is cured to the extent that it is non-tacky, capable of lowering the coefficient of friction, exhibiting plastic flow, and resisting breakdown at points of high stress during the D & I forming steps. Preferably, the resin is also cured to the extent that it does not generate ironing forces substantially in excess of 10,000 pounds nor stripping forces substantially greater than 1200 pounds when employing the screening technique disclosed hereinabove.

Optimum and preferred conditions for the classes of resins listed above have been found to be a cure of about 270°—380°F for about 6 to 8 minutes at a weight of about 5 to 30 milligrams, e.g. 10 milligrams per 4 sq. inches of surface.

While full curing of the resin is undesirable in the process, under curing of the resin is likewise unsatisfactory. When tacky, the resin film sticks to tooling and stripping forces are so high as to prevent successful practice of the process. For example, when an epoxy-phenolic resin is applied in liquid form and baked for six minutes at 240°F, the resin fails by sticking in the cupping press and requires a stripping force that is undesirably high. Partial curing of the resin is indicated to be essential and

such curing must be sufficient to prevent tack, to permit stripping and also to permit the resin to exhibit the viscoelastic properties and plastic flow necessary for its successful function during the forming steps.

Epoxy-phenolic resins suitable for use herein include reaction products of the classic epoxy resin obtained by reaction of epichlorohydrin and bisphenol A, known in the art as diglycidyl ethers of bisphenol A, also referred to in the art as DGEBA resins, and other resins of this type derived from reaction of polyhydric phenols and epihalohydrins with phenol-formaldehyde type resins. Preferred DGEBA reactants are diglycidyl ethers of bisphenol A having average molecular weights of from about 1,000 to about 4,000 and epoxide equivalents of about 425 to about 6,000. In addition to the DGEBA resins, a variety of other epoxides may be employed including epoxidized novolacs. The phenolic component of the reaction product may be methylol phenyl ethers in which the H of the hydroxyl group attached to the phenyl group is substituted by an alkyl, alkenyl or cycloalkyl group, or by an aralkyl or aralkenyl group, as well as the halogenated derivatives thereof. These resins are A-stage methylolphenol resins, i.e., soluble and fusible, and are disclosed and described in U.S. Patent 2,579,330. The preferred resin from this class is 1-allyloxy-2,4-trimethylol benzene. A preferred epoxy-phenolic resin, which also constitutes the preferred class of resin, preferably employed with suitable solvents, catalysts, etc., may be illustrated by a formulation comprising about 50 to 90%, preferably 70% Epon 1007, a DGEBA type epoxy resin having an epoxy equivalent weight of about 2,000—2,500, about 5—50%, preferably about 25% 1-allyloxy-2,4,6-trimethylolbenzene and about 1 to 8%, preferably 4%, polyvinyl butyral.

Epoxy urea formaldehydes are epoxyamino resins, derived by reaction of epoxy ethers such as DGEBA having an average molecular weight of about 900 to 4,000, with the product of condensation of urea and formaldehyde in relative proportions varying from about 95 to 50 parts epoxide to about 5 to 50 parts urea-formaldehyde. Such resins likewise will average molecular weights ranging from about 1,000 to 4,000 and epoxide equivalents of about 425 to about 6,000. A preferred resin for application in liquid form may be illustrated by a mixture of DER667, a DGEBA epoxy resin having an epoxy equivalent weight of 1,600—2,000, and Plaskon 3300, a urea-formaldehyde resin. "Plaskon" is a Registered Trade Mark.

Vinyl organosols are well known compositions comprising polyvinyl chloride resins of relatively high molecular weight, usually at least about 15,000, which resins are relatively insoluble in the usual solvents and are designed to be dispersed in the liquid ingredients of the organosol. The high molecular weight resins are in a finely divided state, generally of a particle size of less than 5 microns. The term "vinyl organosol" as employed herein indicates dispersions of particles of vinyl chloride resins including not only the homopolymer but also copolymers of vinyl chloride with a vinyl carboxylate including vinyl acetate, vinyl butyrate, etc., usually containing at least 50% vinyl chloride in the vinyl copolymer structure. Dispersants include oxygen-containing polar solvents including ketones, e.g. diisobutyl ketone, isophorone; ether alcohols, e.g. 2-butoxy ethanol; other glycol ethers, e.g. diethylene glycol monobutyl ether; esters e.g. ethyl acetate as well as hydrocarbons, e.g. benzene, tolune and mixtures thereof. Also suitable as adhesion-promoting solution resins are other resins including epoxy resins, melamines, acrylic acid resins, phenol formaldehydes, etc. A preferred composition containing this resin type may be illustrated by a dispersion comprising about 80% polyvinyl chloride with a 20% solution resin mixture comprising epoxy, acrylic and urea-formaldehyde resins.

Solution vinyls are also a well known class of resin compositions and include vinyl chloride polymers, the homopolymer as well as copolymers of vinyl chloride with vinyl acetate or other vinyl carboxylates, dissolved in suitable solvents including those mentioned above used as dispersants for the organosols and particularly ketones such as methyl ethyl ketone, hydrocarbons such as benzene, toluene, and mixtures of such solvents. Additionally, the vinyl resins, which are of low molecular weight, usually below about 15,000, may be dissolved in or contain other resins in the solution including epoxides, melamine, phenol-formaldehydes, etc. A preferred composition containing this resin type may be illustrated by vinyl chloride-vinyl acetate copolymer containing about 1% maleic anhydride.

The organic resins identified above may be formulated in suitable solvents or dispersants with pigments and/or fillers and/or internal lubricants, as desired, by means well known in the art. The particular additives, whether solvents or dispersants, etc., are not especially critical. It is necessary, however, that the solvents or dispersants be volatile at the baking temperatures indicated and that they be compatible with all ingredients of the

composition in their useful concentration.

The above classes of organic resins appear to be unique in their ability to meet the criteria above discussed.

Attempts to utilize other types of resins including phenolics, polybutadiene, oleo-resinous, acrylics, U.V.-cured polyesters and others were not successful, in the absence of at least one of the epoxy-phenolic, vinyl organosols, etc. listed above, these other resins being ineffective to lower the coefficient of friction and exhibit suitable viscoelastic properties at graduated bake temperatures between 200°F to about 500°F, and in most cases were unable to withstand the forces generated in the initial cup forming step. None of these other resins were satisfactory for forming the ironed shell.

The following examples will serve to further illustrate the invention.

Example 1.

With reference to Figures 1 and 2, which are schematics of a D & I die stack showing the workpiece, cup and blank respectively, as it progresses through the steps of the process, CMQ steel is coated on both sides with an epoxy phenolic resin composition at a coating weight of about 10 mg./4 in.$^2$ and cured by baking in an oven at 300°F for about 6 minutes. After drying, a 2.610 in. diameter × 0.0113 in thick × 2.250 in. in height cup or a 5.694 in. × .0145 in. to .0150 in. thick blank was placed over the respective die assembly, schematically illustrated, in either a cup-fed Stolle or Standun B-1 bodymaker (Standun, Inc., Compton, California), or a blank-fed XBB press (American Can Company). Coolant comprising an emulsion of 95% water and 5% commercially available mineral oil, Prosol (Mobil Oil Company), circulates through the die assembly, and contacts the workpiece. "Prosol" is a Registered Trade Mark. In the cup-fed procedure, (Fig. 1), a punch, not shown, then forces the cup 10 through the ironing dies 15, 16 and 17, which progressively result in drawing the cup into a shallow seamless cup having a sidewall thickness of 0.0102 inch in the first die 15 and 0.0062 inch in the second die 16. As the punch continues to force the metal workpiece through the die assembly 12, the shallow cup 10 is elongated and the side walls are ironed through passage through the ironing dies 15 to 17 to a final elongated, thin-walled 5 inch container 20, having a sidewall thickness of about 0.0038 inch and a bottom wall thickness of 0.0113 inch which corresponds to the thickness of the original blank. The 5 inch container 20 is subsequently removed from the ironing punch by a stripping operation. In the blank-fed procedure, the blank 11 is forced through the drawing and ironing dies 21, 22 and 23 (Fig. 2) which result in the production of a shallow seamless cup having a sidewall thickness of 0.0125 inch in the first die 21, 0.0108 inch in the second die 22 and 0.0055 inch in the third die 23, resulting in a final elongated, thin-walled 5 inch container 30 having a sidewall thickness of 0.0055 inch and a bottom wall thickness of about 0.0145 inch. Ironing forces exerted during the procedures were as indicated in Figure 4, about 8,000 pounds, and stripping forces (Figure 5) were about 950 pounds.

The container 20 or 30, with a suitable bottom profile 32 imparted thereto, is now ready for subsequent treatment as desired, including washing, decorating, coating, necking-in at 33 and flanging at 34 to produce a container 35, for example, as illustrated in Figure 3. In the preferred embodiment, the desired bottom profile 32 is also formed by the ironing punch. It is to be understood, however, that while this example and the schematics employ a three-die stack, the number of dies may be varied as desired to produce the container.

The above example has been run on a 2400 can lot and has been found to be remarkably free from failures.

When the above example was repeated with backplate, but omitting application of the resin, only 1 out of 12 cans could be run successfully because of broken cans due to galling.

When the example was repeated with epoxy-phenolic-coated tinplate on either a cup-fed or blank-fed Stolle bodymaker, with either matte or bright tinplate, the results were substantially the same as those achieved with precoated steel.

The most striking effect of the resin film may be seen by comparison with the attempts to draw and iron uncoated, unplated steel. Drawing and ironing of this material with various and extensive oily type lubricants has resulted in a frequency of ironing failures triggered by localized breakdown of the lubricant that is intolerable for an efficient, economical high-speed commercial process. Localized failure of lubricants has caused galling which leads to rapid and progressive deterioration of tooling and workpieces. For example, for 211 × 413 drawn and ironed cans with similar steel, tooling and lubricants, only 2 cans out of a 24-can lot could be run successfully, corresponding to a 92% wall failure, while with precoated steel according to the invention, only 1 wall failure was experienced with 3,200 cans run, corresponding to a wall failure rate of 0.031%.

Examples 2 to 10.

The procedure of Example 1 was repeated using the Stolle bodymaker and a cup-fed procedure employing the epoxy-phenolic resin of Example 1 as the inside coating and various organic resins as outside coatings. Bake temperatures, time and resin weights were varied as indicated, and the outside coating evaluated for integrity. The results were obtained in the Table which follows:

TABLE

| Resin Type | Form Applied | Weight | 6 minutes Cure Temperature, °F and Results 275 | 300 | 320 | 340 | 360 | 380 |
|---|---|---|---|---|---|---|---|---|
| Example No. 2) Phenolic | Coating | 6 mg. | — | Satisfactory on Cup; Unsatisfactory on Shell; Complete Sidewall Removal | Unsatisfactory on Cup | Unsatisfactory on Cup; Poor Integrity | Unsatisfactory on Cup; Poor Integrity | Unsatisfactory on Cup; Poor Integrity |
| 3) Polybutadiene | ,, | 12 mg. | — | ,, | ,, | ,, | ,, | ,, |
| 4) Oleoresinous | ,, | ,, | — | ,, | ,, | ,, | ,, | ,, |
| 5) Acrylic | ,, | ,, | — | Unsatisfactory; No Cup formed | Unsatisfactory; No Cup formed | Unsatisfactory; No Cup formed | Unsatisfactory on Cup; Coating Soft | Unsatisfactory on Cup; Coating Soft |
| 6) Epoxy | ,, | ,, | *U.V. Cure | 120 fpm Unsatisfactory on Cup; Severe Flaking | 60 fpm Unsatisfactory on Cup; Moderate Flaking | 60 fpm +300F for 6 minutes Unsatisfactory On Cup; Moderate Flaking | — | — |
| 7) Polyester | ,, | 13 mg. | *U.V. Cure | 30 fpm Unsatisfactory on Cup; Poor Integrity | — | 30 fpm +300F for 6 minutes Unsatisfactory On Cup; Poor Integrity | — | — |
| 8) Acrylic (Water-base electrocoat) | ,, | 12 mg. | Coating Breakup on Upper 1/3 of Sidewall; Coating Removal on Shell | Unsatisfactory on Cup; Coating Removal on Sidewall | — | (*350°) Unsatisfactory on Cup; Coating Removal on Sidewall | — | — |

In the table, the results as reported indicate the following:

(a) "Unsatisfactory on Cup" indicates the resin was ineffective to withstand the forces generated in the first drawing die, resulting in earing, galling and poor integrity where sufficient coating remains to evaluate this property.

(b) "Unsatisfactory on Shell" indicates the resin was effective through the first drawing die but ineffective to withstand the forces generated in the first ironing die.

(c) "No cup" indicates that metal containing the resin could not be formed into a cup in the first die.

Example 9.

The procedure of Example 1 was repeated except that blanks were cut from sheet coated with a solution vinyl resin at 10 mgs./4 in.$^2$, cured at 340°F for six minutes and utilized in a blank-fed procedure on an XBB bodymaker. Results were substantially the same as achieved in Example 1.

Example 10.

The procedure of Example 1 was repeated except that a blank-fed procedure was employed using the XBB bodymaker and an epoxy-urea formaldehyde resin was applied at 12 mgs./4 in.$^2$ and cured for 6 minutes at 400°F. Results were substantially the same as achieved in Example 1.

Example 11.

The procedure of Example 1 was repeated except that a blank-fed procedure was employed using the XBB bodymaker. In this run, the outside of the metal sheet was coated with a vinyl organosol at 30 mgs./4 in.$^2$ and cured at 380°F for 6 minutes, after which the inside was coated with an epoxy-phenolic at 15 mgs./4 in.$^2$ and cured for six minutes at 300°F. The results were substantially the same as obtained in Example 1.

It will be apparent from these experiments that the degree of curing is a critical feature in this invention.

Variations in the procedure above described may be practiced as desired. For example, combinations of the resins may be employed. In a preferred embodiment, the side of the blank that is to form the inside of the container is coated with epoxy-phenolic resin while the outside surface is coated with a vinyl organosol. Additionally, the same resin may be applied at different weights; for example, a polyvinyl chloride organosol may be applied at 30 mgs. on the outside and 8 mgs. on the inside, both with a 380° bake.

Various lubricants known in the art may be employed to aid in lowering the coefficient of friction between the workpiece and the apparatus, if desired. It will be understood, however, that such auxiliary lubricants, whether external or internal, are optional and are not necessary, since lubrication is a feature of the organic resin and the resin is effective for this purpose in the absence of additional compounds. Auxiliary lubricants suitable for use herein may include any conventional compounds, as long as such a compound does not soften or tackify the resin film applied to the metal or otherwise affect its flow properties during the process. Examples of suitable external lubricants include dioctyl sebacate, dibutyl sebacate, mineral oil, acetylated tributyl citrate, deionized water, "Prosol", etc. Dioctyl sebacate, acetylated tributyl citrate and/or water are especially preferred as the auxiliary external lubricant herein, since it has been found that use of such compounds is effective to eliminate or at least simplify subsequent washing steps. For example, the containers may be cleansed merely by baking in an oven at a temperature sufficient to remove the dioctyl sebacate, when dioctyl sebacate is the auxiliary lubricant, without the necessity for further washing.

Examples of suitable internal lubricants include amide type waxes, e.g. ethylene bis stearamide; alkyl aryl siloxanes; ester type lubricants, e.g. dioctyl sebacate, acetylated tributyl citrate, tallow; glycol fatty acid esters; hydrocarbon type lubricants, e.g., mineral oil, higher molecular weight waxes; lanolin, spermaceti, polyolefin based lubricants, polytetrafluoroethylene lubricants, etc.

When such auxiliary lubricants, either internal or external, are employed, they may be used in proportions ranging from 1 to 15% by weight of the dry film.

Example 12.

Example 1 was repeated employing a horizontal wall ironer — HWI (American Can Company), using a tin-free CMQ steel cup, the coating of Example 1 having been applied and baked prior to forming the cup, and the cup having been washed to remove any residual oil which might be present from the cupping press.

Normal coolant (95% water and 5% "Prosol") employed in Example 1 was completely removed from the HWI and the system was flushed with water. The system, without the use of any lubricant or coolant whatsoever, was then employed to form several D & I containers as in Example 1. The resin film had good integrity both inside and outside the ironed shell, and was satisfactory through all of the ironing dies.

There were no unusual effects noted during this experiment run without coolant or auxiliary lubricant, although an extensive run without coolant would be expected to generate excessive heat after an extended period. The experiment is indicative, however, of the special properties of the resin film and its ability to promote a lowered coefficient of friction, resist breakdown at localized points of high stress, and exhibit plastic flow during the D & I process, and also of its ability to withstand the effects of ironing and stripping forces generated without decomposition and exfoliation.

The present invention provides a ready means for simplifying the conventional steps involved in manufacture of a D & I container. These steps, after forming, normally involve trimming, washing, decorating, interior coating, necking, flanging and palletizing.

Throughout the previously conventional metal-forming and trimming operations, for example, the container shell is normally covered by a film of oily lubricant which must be removed by cleaning prior to decorating, usually with heated aqueous detergent sprays. In a typical washer, cans are conveyed through a series of cleaning and treating zones. After cleaning, the surfaces of ironed metal, especially tinplate or blackplate, must be chemically passivated to prevent darkening during baking and to prevent loss of enamel adhesion. The final step in a washer is usually a deionized water rinse to eliminate residues from the spray solutions. The ecological and economical importance of this invention becomes readily apparent when it is considered that the resins utilized and preapplied include many of the coatings normally applied to containers after forming for decoration, as size coats for protection against corrosion, etc. With tinplate and blackplate particularly, conventionally the entire bottom end must be sprayed with organic coating or otherwise treated to prevent rusting. The container formed in accordance with this invention already has present on its surfaces a protective and/or decoratable coating which protects against corrosion and makes it possible to eliminate the necessity to apply a size coating after forming. The container as formed provides a base for applying decorative top coats and the bottom end, which is particularly hard to protect by conventional means, is already protected as formed. Moreover, oily lubricants are not necessary in forming and thus do not have to be removed. If, however, a lubricant is employed, it can be selected to be a volatile one, for example, the dioctyl sebacate above described, which can be baked off, virtually eliminating the need for multiple washing steps and washing equipment. Elimination of large numbers of heated aqueous spray applications would result in substantial energy savings, which is an increasingly significant feature and advantage.

Additionally, containers derived from stock carrying organic resins appear to exhibit better adhesion to a wider variety of inks, and coatings and topcoats, where utilized, may be applied at reduced weights. The adhesion to a variety of inks is particularly important, since currently only a few inks and varnishes are satisfactory for use with unsized tinplate because of poor adhesion. The present invention provides a greater variety in the selection of such inks. Another advantage is in the technique of film labeling wherein decorated labels of plastic film are adhered to the container surface. Adhesion of such labels to containers having organic resin film applied, as formed herein, has been found easier to obtain and greatly simplifies film labeling procedures.

Reflow of the coating which may occur during forming or subsequently during washing, decorating or interior coating, may effectively heal and eliminate areas of exposed metal both on the interior surfaces, thereby preventing metal ion dissolution into products, and on the exterior surfaces, resulting in a container having a glossy surface finish. Such reflow of the coating further improves adhesion and serves to remove any flaws in the resin film that may result from the forming operation.

It is apparent from the foregoing description of the method that the organic resin films on the interior and exterior sidewall surfaces of the drawn and ironed container are subjected to extreme and varying mechanical actions. The internal sidewall surface is forced to undergo a 90° compressive bend around a punch and a tensional force during ironing, whereas the exterior sidewall surface undergoes the 90° tensional bend in the drawing and is then exposed to an extrusion or "squeezing" action when passing through the forming dies. The bottom end of the container has not been essentially deformed. It is apparent that the exterior resin film on the container has undergone a deformation and change different from that of the interior resin film. With each ironing step, the interior resin film undergoes severe deformation as it is squeezed between the particular ironing face and the mandrel or punch. On the other hand, the organic resin film on the exterior surface of the container is thinned by each succeeding ironing die which reduces the thickness of the sidewall and increases its height, so that the resin

film on the exterior sidewall of the container has been forced to undergo a 90° tensional bend in the drawing operation and then elongation or stretching during the ironing.

It should be noted that both the interior and exterior surfaces of the bottom end of the container retain the as-deposited organic resin films.

It should be obvious from the foregoing description that it was extremely surprising that organic resins could be found which were able to withstand the extreme stresses and conditions involved in drawing and ironing operations applied to ferrous metal workpieces, resulting in the prevention of galling of the metal substrate on the drawing and ironing dies while providing a virtually continuous film.

WHAT WE CLAIM IS:—

1. A method of drawing and ironing thin-walled cylindrical articles from flat sheet steel or tinplate comprising the steps of:

(a) applying a composition comprising an organic resin to at least one surface of the sheet;

(b) subjecting the sheet carrying the resin to an elevated temperature for a period of time sufficient to effect adhesion to the metal and a partial curing of the resin;

(c) forming a workpiece from the resin-carrying sheet;

(d) forcing the workpiece through drawing and ironing dies on a punch, to form an elongated cylindrical article the sidewalls of which are substantially reduced in thickness compared to the thickness of the sheet initially, and

(e) removing the article from the punch; the resin being cured in step (b) to the extent that it is retained on the sheet, is capable of lowering the coefficient of friction between the sheet and the drawing and ironing tooling, and exhibits plastic flow at high stress levels during the drawing and ironing steps.

2. The method according to Claim 1, wherein the resin chosen is one capable of exhibiting viscoelastic properties during drawing and ironing.

3. The method according to Claim 1 or Claim 2, wherein the workpiece is formed as a circular metal blank.

4. The method according to Claim 1 or Claim 2, wherein the workpiece is formed as a seamless cup which is forced through a series of ironing dies.

5. The method according to any of Claims 1 to 4, wherein the resin is selected from the group consisting of epoxy-phenolic, epoxy-urea formaldehyde, vinyl organosol and solution vinyl.

6. The method according to any of Claims 1 to 5, wherein the resin composition includes a lubricant.

7. The method according to any of Claims 1 to 5, wherein a lubricant is applied to the resin-carrying sheet after performing step (b).

8. The method according to Claim 6 or Claim 7 wherein the lubricant is selected from the group consisting of dioctyl sebacate, acetylated tributyl citrate, mineral oil and water, and mixtures thereof.

9. The method according to Claim 5 or any claim dependent on Claim 5, wherein an epoxy-phenolic resin is applied to that surface of the sheet which is destined to be the interior surface of the cylindrical article, and a vinyl organosol resin is applied to that surface of the sheet which is destined to be the exterior surface of the article.

10. A method according to any of the preceding claims, wherein the organic resin is applied to the surfaces of the steel or tinplate sheet which is then formed into a seamless drawn cup, the seamless drawn cup being placed over axially-aligned drawing and ironing dies and forced through the dies with a reciprocal punch to form an elongated cylindrical article having a sidewall substantially reduced from the original thickness of the sheet and a bottom end wall substantially equal in thickness to the original thickness.

11. A method of drawing and ironing thin-walled seamless container bodies, substantially as herein described with reference to the accompanying drawings.

12. A method of drawing and ironing thin-walled seamless container bodies in accordance with any one of Examples 1, 9, 10, 11 and 12 described herein.

13. A drawn and ironed container body made by the method claimed in any of Claims 1 to 12.

14. A drawn and ironed seamless sheet steel or tinplate container body having integral bottom and side walls, and an organic resin film coating bonded directly to the said walls, the resin being selected from the group comprising epoxy-phenolic, epoxy-urea formaldehyde, vinyl organosol and solution vinyl.

15. A steel or tinplate drawn and ironed container body substantially as herein described with reference to the accompanying drawings.

16. A container comprising the container body claimed in Claim 13, 14 or 15, fitted with a top end closure.

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FIG. 1

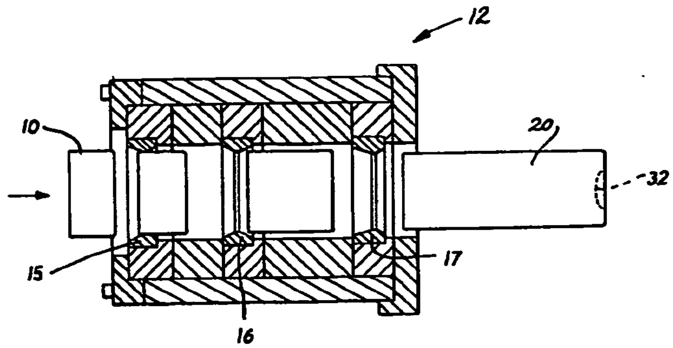



FIG. 3

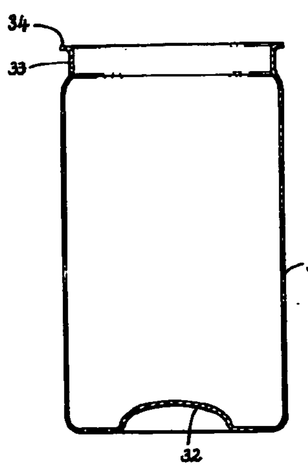
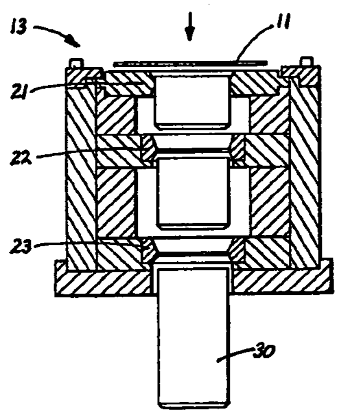



FIG. 2



1517732 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 2

FIG. 4

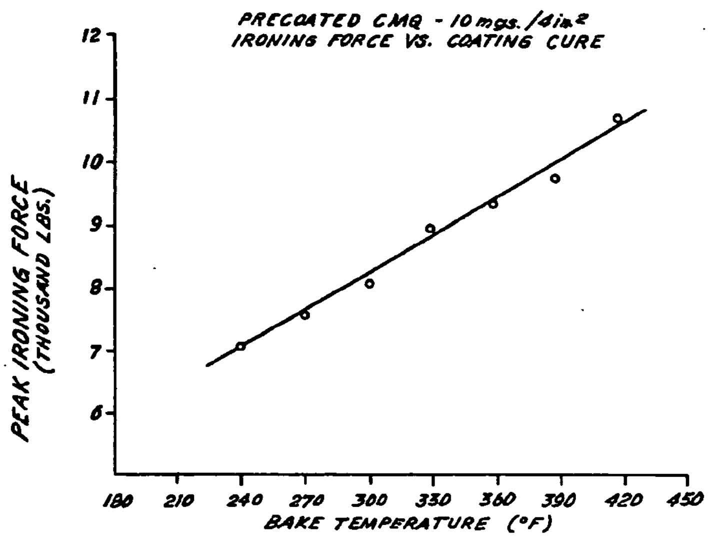



FIG. 5